UM10903

SSL5261DB1350 120 V/18 W and 230 V/36 W dual-stage dimmable non-isolated LED driver board with VLC option

Rev. 1 — 3 November 2015 **User manual**

Document information

Info	Content
Keywords	SSL5261DB1350, SSL5261AT, SSL5261PT, SSL5257TE, SSL applications, dual-stage, boost PFC, buck, dimmable, non-isolated LED driver, microcontroller/auxiliary power supply, Visual Light Communication (VLC)
Abstract	This user manual describes the SSL5261DB1350 dual-stage dimmable non-isolated LED driver board used in Solid-State Lighting (SSL) fixture applications. The SSL5261DB1350 LED driver board includes an auxiliary supply for a microcontroller used, for instance, in smart lighting application. The SSL5261DB1350 LED driver board accommodates for Visual Light Communication (VLC) applications. It features the SSL5261AT, SSL5261PT, and SSL5257TE ICs.

Revision history

Rev	Date	Description
v.1	20151103	first issue

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1. Introduction

WARNING

Lethal voltage and fire ignition hazard

The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire.

This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

The SSL5261DB1350 is a demo board featuring a dual-stage dimmable non-isolated power supply consisting of a boost PFC using the SSL5261AT, a buck controller using the SSL5261PT and a 3.3 V microcontroller/auxiliary buck power supply using the SSL5257TE. The PCB incorporates a fixture form factor with a minimum component count.

Target applications are fixture, downlight, and smart lighting applications using microcontrollers having both analog and Pulse Width Modulation (PWM) dimming capabilities. Visual Light Communication (VLC) is accommodated for in the application.

The single PCB dimensions are 110 mm × 39 mm × 24 mm. It is designed using CEM-3 or FR4 material and a copper thickness of 80 μm.

The board provides a simple and effective solution for dual-stage dimmable non-isolated power supplies.

1.1 Features

- PFC controller featuring the SSL5261AT
- Buck controller featuring the SSL5261PT
- 3.3 V μC/auxiliary supply for usage with microcontrollers featuring the SSL5257TE
- Excellent line and load regulation
- Open-string protection
- Output short Protection (OSP)
- High power factor and low Total Harmonic Distortion (THD)
- High efficiency
- Fast start-up
- Single-sided PCB with dimensions of 110 mm × 39 mm × 24 mm

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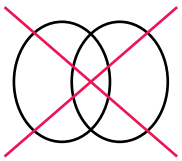
2. Safety warning

The SSL5261DB1350 demo board is connected to the mains input. Avoid touching the board while it is connected to the mains voltage and when it is in operation. Isolated housing is obligatory when used in uncontrolled, non-laboratory environments. Galvanic isolation from the mains phase using a fixed or variable mains transformer is always recommended. Figure 1 shows the symbols that identify the isolated and non-isolated devices. Use a diffuser cover to avoid LED light in contact with the eyes.

a. Isolated



b. Not isolated

Fig 1. Isolation symbols

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3. Specifications

Table 1. SSL5261DB1350 specifications

Symbol	Parameter	Value at V_{mains} = 120 V	Value at V_{mains} = 230 V
-	IC used	SSL5261AT	SSL5261AT
		SSL5261PT	SSL5261PT
		SSL5257TE	SSL5257TE
V_{mains}	AC mains supply voltage	120 V (AC); ±10 %	230 V (AC); ±10 %
P_{out}	nominal output power	18 W	36 W
V_{LED}	LED output voltage	40 V to 80 V (60 V nominal)	100 V to 125 V (120 V nominal)
I_{LED}	LED output current	300 mA	300 mA
$I_{LED(ripple)}$[1]	LED output current ripple	< 5 %; 120 Hz	< 5 %; 100 Hz
$\Delta I_{LED(Vmains)}/\Delta I_{LED(nom)}$	line regulation	< ±0.1 % at V_{mains} = ±10 %	< ±0.1 % at V_{mains} = ±10 %
$\Delta I_{LED(VLED)}/\Delta I_{LED(nom)}$	load regulation	< ±1 % at V_{LED} = ±10 %	< ±0.5 % at V_{LED} = ±10 %
η	efficiency	> 89 %	> 92 %
PF	power factor	> 0.97	> 0.97
THD	total harmonic distortion	< 12 %	< 12 %
$t_{startup}$	start-up time	< 300 ms	< 300 ms
f_{sw}	switching frequency	PFC: 45 kHz to 150 kHz; buck: 75 kHz	PFC: 45 kHz to 150 kHz; buck: 110 kHz
OVP	overvoltage protection or open-string protection	V_{LED} > 125 V; P_{in} < 0.5 W	V_{LED} > 125 V; P_{in} < 0.6 W
OSP[2]	output short protection	V_{LED} = 0 V; P_{in} < 1.1 W	V_{LED} = 0 V; P_{in} < 1.1 W
STBY	standby function	P_{in} < 75 mW	P_{in} < 150 mW
-	board size (L × W × H)	110 mm × 39 mm × 24 mm	110 mm × 39 mm × 24 mm

[1] $$I_{LED(ripple)}\,(\%) = \left(\frac{I_{LED(max)} - I_{LED(min)}}{I_{LED(max)} + I_{LED(min)}}\right) \cdot 100$$

[2] Open-string protection is triggered at V_{LED} > 125 V

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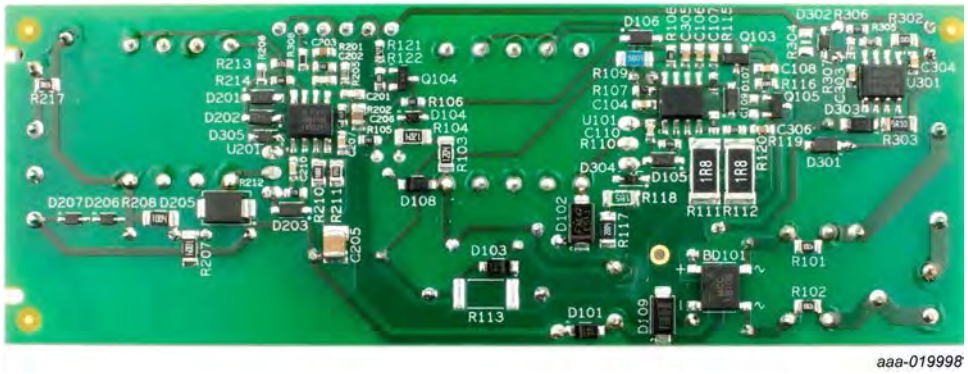
4. Board photographs

a. Top view



b. Bottom view

Fig 2. SSL5261DB1350 demo board photographs

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5. Board connections

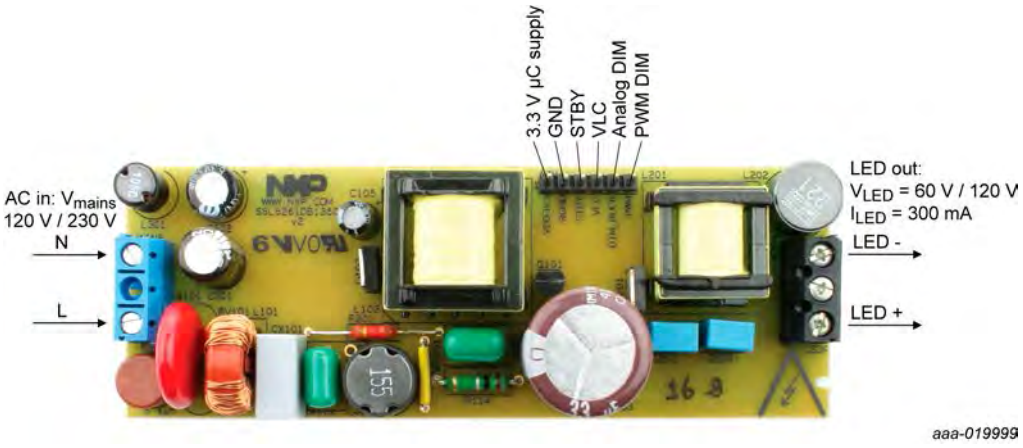

Fig 3. SSL5261DB1350 demo board connections

- STBY: 0 V to 5 V
- VLC: 500 Hz data stream; 300 mV peak-to-peak; 25 % modulation of I_{LED}
- Analog dimming: 0 V to 0.6 V
- PWM dimming: 0 V to 3.3 V; 1 kHz; duty factor variable 0 % to 100 %

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6. Functional description

6.1 PFC controller

Figure 4 shows a simplified SSL5261AT internal block schematic, representing the control of the PFC controller. Figure 10 shows the schematic of the complete PFC application. This functional description refers to Figure 4 and Figure 10.

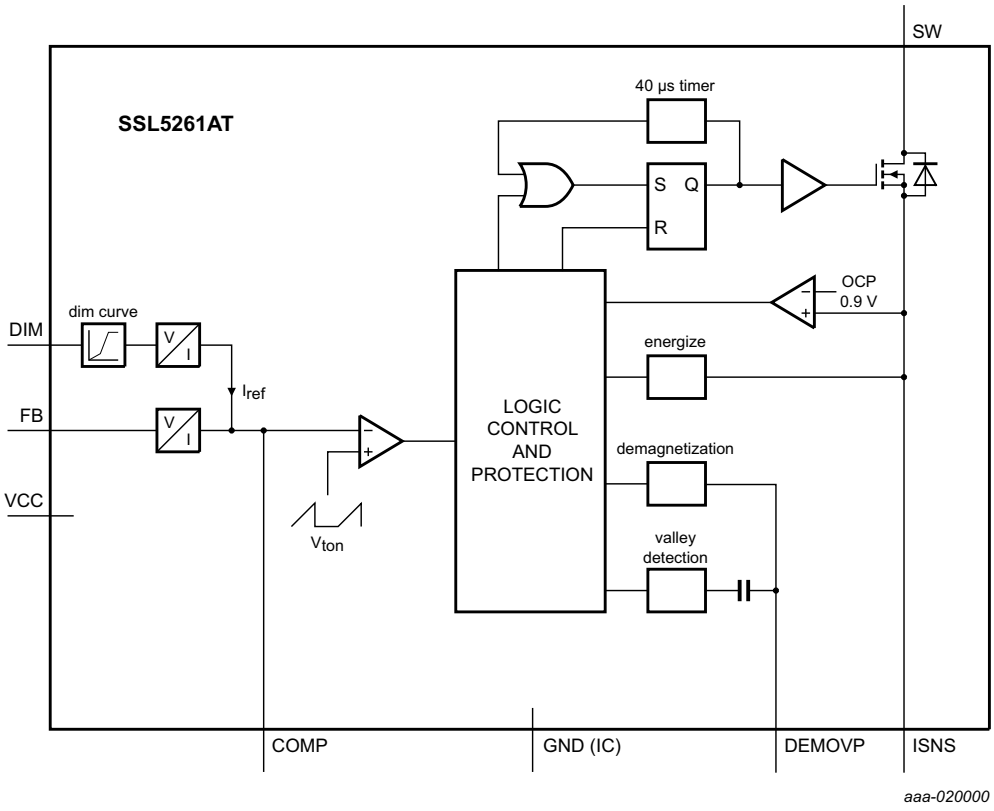

Fig 4. Simplified internal block schematic describing the SSL5261AT control function

The DIM pin is connected to VCC via pull-up resistor R107 in the application. The corresponding current from the internal V/I converter is at its maximum value I_{ref}. The average current at the V/I converter output is regulated to I_{ref} during t_{off} by adapting the regulation voltage on the FB pin to 155 mV (See Ref. 1). The voltage on the COMP pin changes accordingly and determines the t_{on} time.

When $V_{ton} > V_{COMP}$ or $V_{ISNS} > 0.9$ V, the secondary stroke begins. When demagnetization/valley is detected at the DEMOVP pin and the energize level is reached or when the 40 µs timer is completed, the primary stroke begins.

The voltage across the auxiliary winding of L103 determines the voltage on the DEMOVP pin. To ensure that the PFC converter switches off during large inrush currents through capacitor C103 when mains voltage is applied to the LED driver, resistors R113//R114 are also connected to the DEMOVP pin.

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The current through inductor L103 during the primary stroke (i.e. during the t_{on} period when the MOSFET is switched on) and through resistors R111//R112 determines the voltage on the ISNS pin (V_{ISNS}). The PFC converter operates in Boundary Conduction Mode (BCM) throughout the mains cycle. The switching frequency varies from 45 kHz to 150 kHz during each mains cycle.

During regulation, the voltage on the FB pin is 150 mV. The result is a current 100 μA flowing through resistor R120. The voltage on the DIV node is 12 V during normal operation. If this voltage becomes greater than V_{CC} + 2 V_{be} = 17 V (i.e. for an overvoltage condition on V_{BUS}), transistor Q105 is in conduction. The COMP pin is discharged to ground via transistor Q103, the PFC converter stops switching.

Diode D107 (BAS116H) ensures loop protection. If either resistor R117 or resistor R118 is open circuit, the COMP pin is discharged to ground via diode D107. The PFC converter then stops switching. To ensure minimum leakage current at the COMP pin when diode D107 is reverse biased, it is a low-leakage diode.

To ensure reliable PFC start-up, the time constant R106 = 33 kΩ/C105 = 1 μF is chosen so that the V_{CC} increases with the DIV signal (i.e. determined by V_{BUS} via D101 path). The STBY function switches off the combined current source transistor Q101. The PFC (SSL5261AT) and the buck (SSL5261PT) converters are switched off. Low standby power is reached.

During normal operation, the 100 μA current flowing through resistor R120 and the voltage across the other resistors R117, R118, R119 because of this current, determine the voltage (V_{BUS}) supplied to the buck converter.

6.2 3.3 V microcontroller/auxiliary supply

For a detailed description, see the *SSL5257DB1351 3.3 V standby/auxiliary power supply to power a microcontroller for smart lighting interfaces* user manual (Ref. 4).

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6.3 Buck controller supporting PWM and VLC

Figure 5 shows a simplified SSL5261PT internal block schematic representing the control of the buck controller. Figure 12 shows the complete application schematic of the buck controller. This function description refers to Figure 5 and Figure 12.

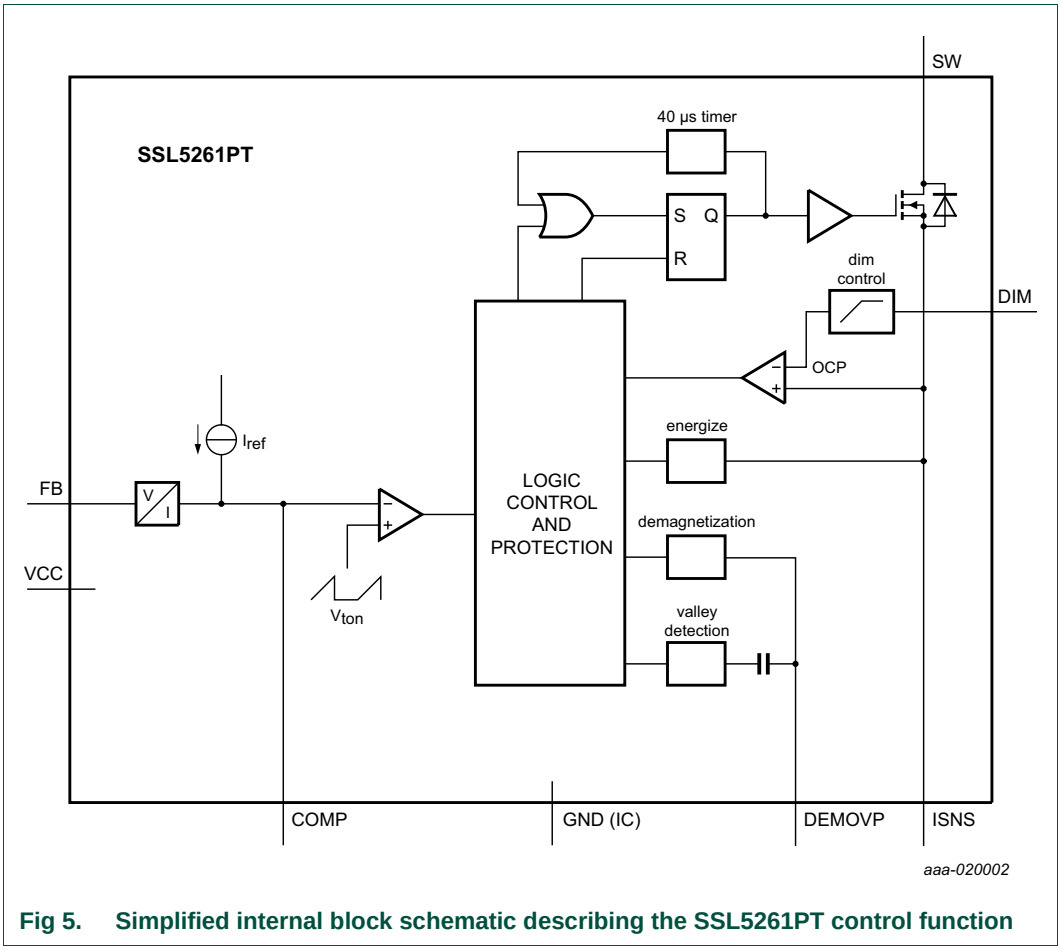

Fig 5. Simplified internal block schematic describing the SSL5261PT control function

The main difference with the SSL5261AT version is the connection of the DIM pin. The SSL5261PT controls the peak current. The SSL5261AT controls the average set point. In this way, the SSL5261PT version can be used for PWM dimming.

In the application, the DIM pin is connected to V_{CC} via resistor R202 and to ground via resistor R201. The voltage on the DIM pin is 0.6 V. The voltage on the DIM pin sets the internal OverCurrent Protection (OCP) voltage via the dim control curve and consequently the voltage on the ISNS pin $V_{(ISNS)}$. For more information about peak dimming control, see the *SSL5261PT data sheet* (Ref. 2).

The FB pin is connected to ground, so it has no influence on the regulation.

The capacitor (C201) on the COMP pin is charged to its maximum level with a current I_{REF}.

When $V_{ton} > V_{COMP}$ or $V_{ISNS} > 0.9$ V, the secondary stroke begins. When demagnetization/valley is detected at the DEMOVP pin and the energize level is reached or when the 40 µs timer is completed, the primary stroke begins.

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The voltage across the auxiliary winding of inductor L103 determines the voltage on the DEMOVP pin. The voltage across the auxiliary winding, resistors R213, R214, and R206, and diodes D201 and D202 ensures valley detection, demagnetization, open-string protection of the LEDs, and short circuit protection of the driver output. The auxiliary voltage is V_{BUS} / turns ratio during the secondary stroke, which is 40 V (V_{BUS} = 400 V and turns ratio = 10).

The current through inductor L201 during the primary stroke (i.e. during the t_{on} period when the MOSFET is switched on) and through resistors R210//R211 determines the voltage on the ISNS pin (V_{ISNS}).

The buck operates in BCM. The switching frequency is constant at 110 kHz at V_{LED} = 120 V.

With the DIM pin set to 0.6 V, a VLC data stream can be AC-coupled via capacitor C203 with maximum 25 % LED current modulation. The VLC data stream has a repetition rate of 500 Hz with an average value of zero. So, the VLC data stream does not influence the average LED current.

The DIM and COMP pins also realize analog and PWM dimming. For analog dimming, the minimum dimming is 10 % of the nominal LED current. For PWM dimming, a 3.3 V/1 kHz PWM signal is supplied to the COMP pin via resistor R205 (100 kΩ), realizing a dimming range from 0 % to 100 %. When using the VLC option, do not use analog or PWM dimming functions.

Zener diodes D206 and D207 limit the voltage on the output to 125 V during an open-string condition without efficiency loss. Resistors R207 and R208 ensure that the LED voltage is equally divided across output capacitors C209 and C211.

Output capacitors C209, C211, and inductor L202 filters the high-frequency switching signal. Damping resistor R217 dampens ringing of the modulated LED current where the LED current is modulated with a 500 Hz VLC data stream.

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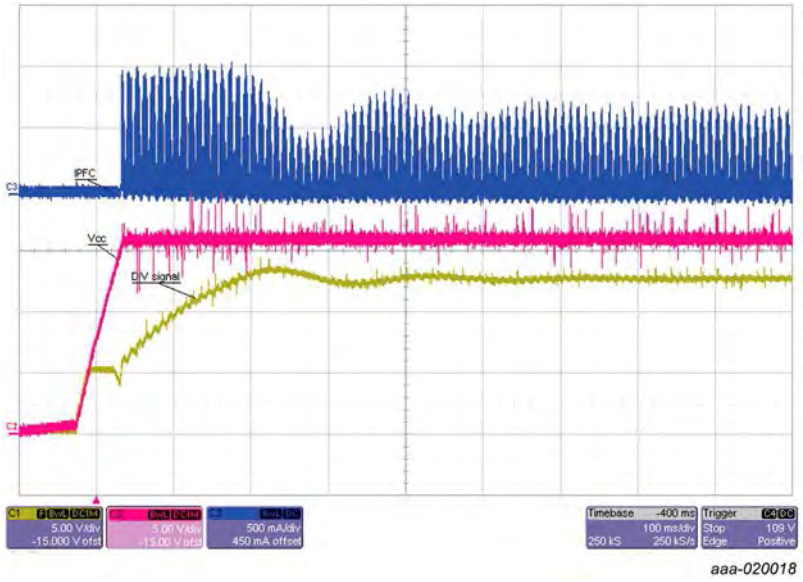
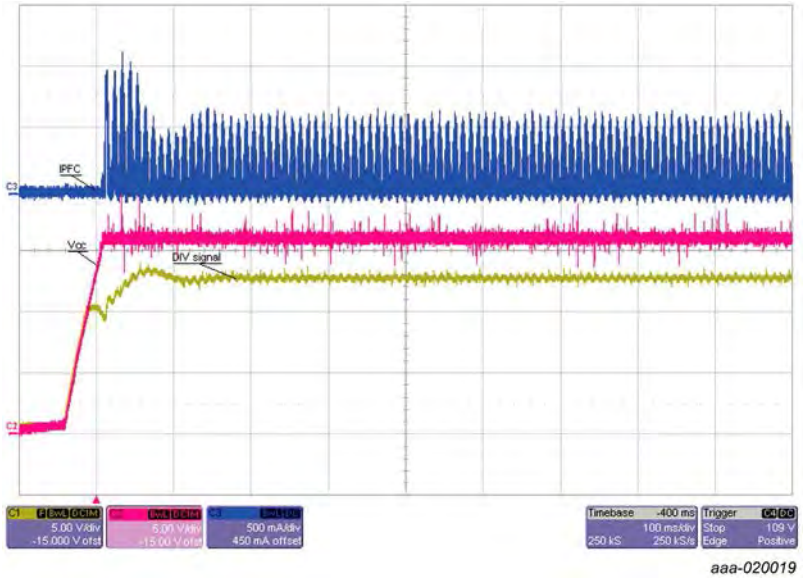
7. Performance

7.1 Start-up



a. V_{mains} = 120 V



b. V_{mains} = 230 V

Fig 6. SSL5261DB1350 waveforms for V_{CC}, DIV signal, and I_{PFC}

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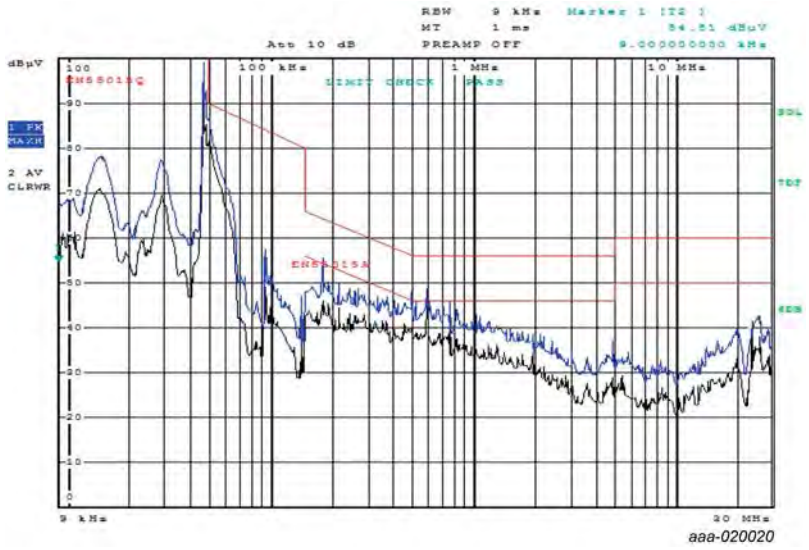
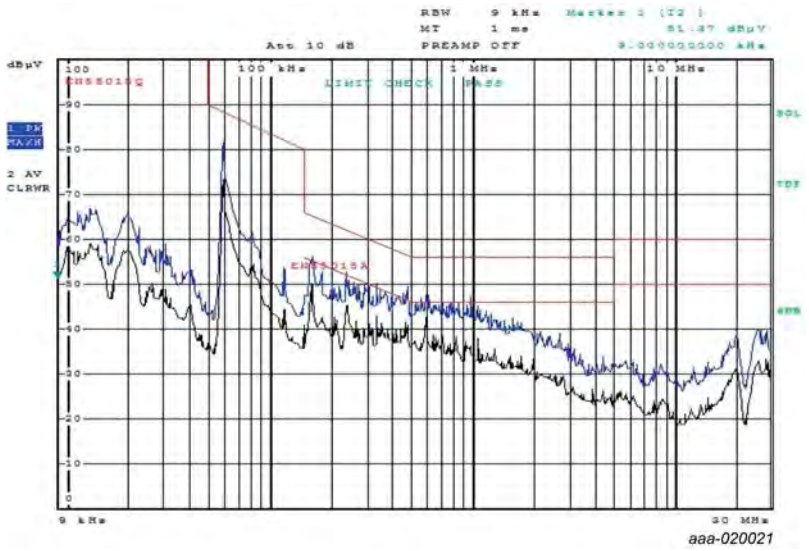
7.2 ElectroMagnetic Interference (EMI)



a. V_{mains} = 120 V



b. V_{mains} = 230 V

Fig 7. SSL5261DB1350 demo board: EMI performance

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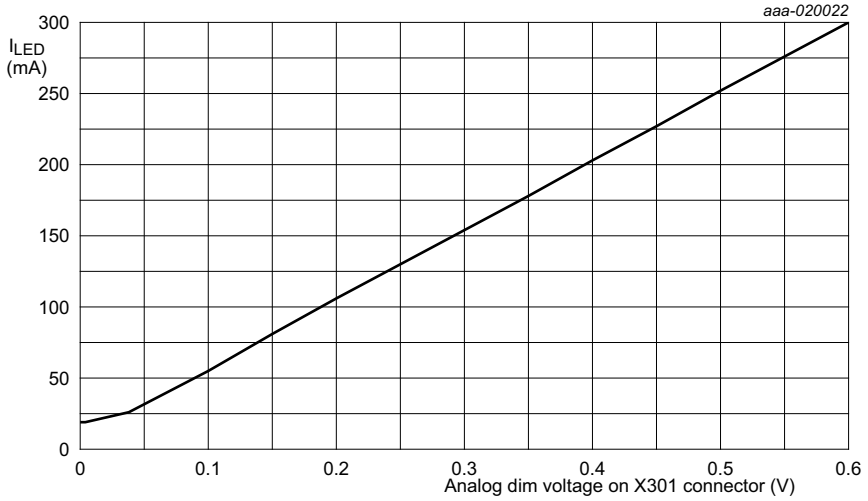
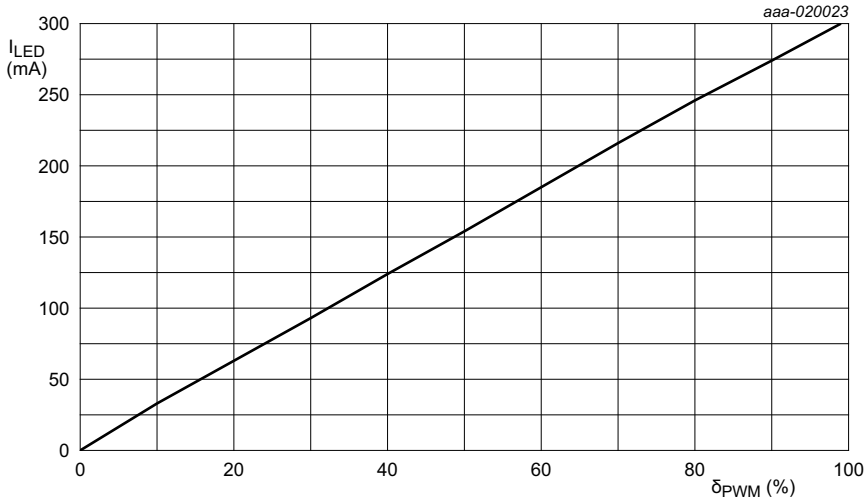
7.3 Dimming



a. Analog



b. PWM

Fig 8. SSL5261DB1350: Dimming of SSL5261PT

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7.4 VLC data modulation of LED current

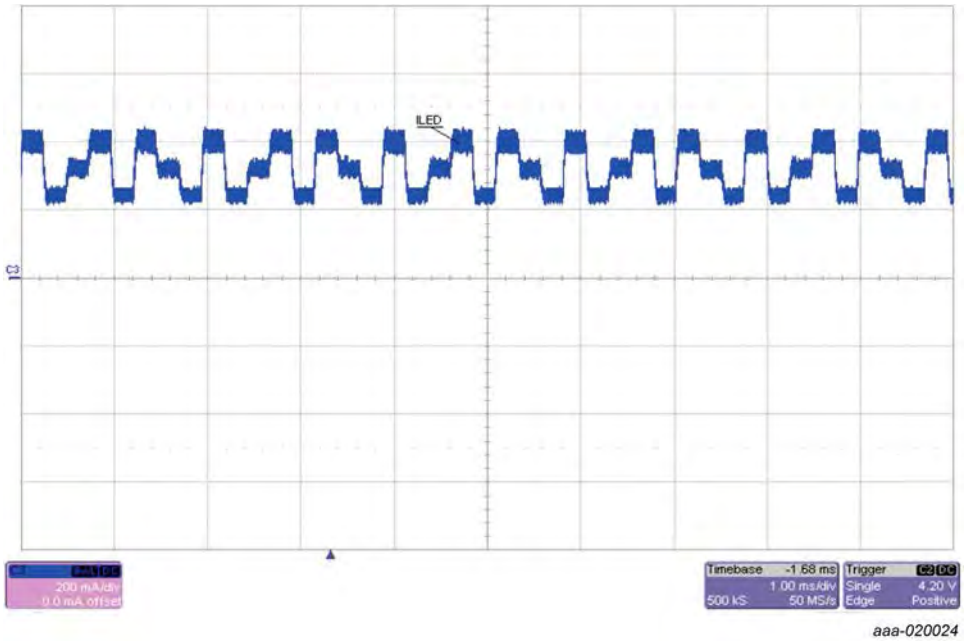

Fig 9. VLC data modulation of LED current

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8. Schematic

8.1 PFC controller

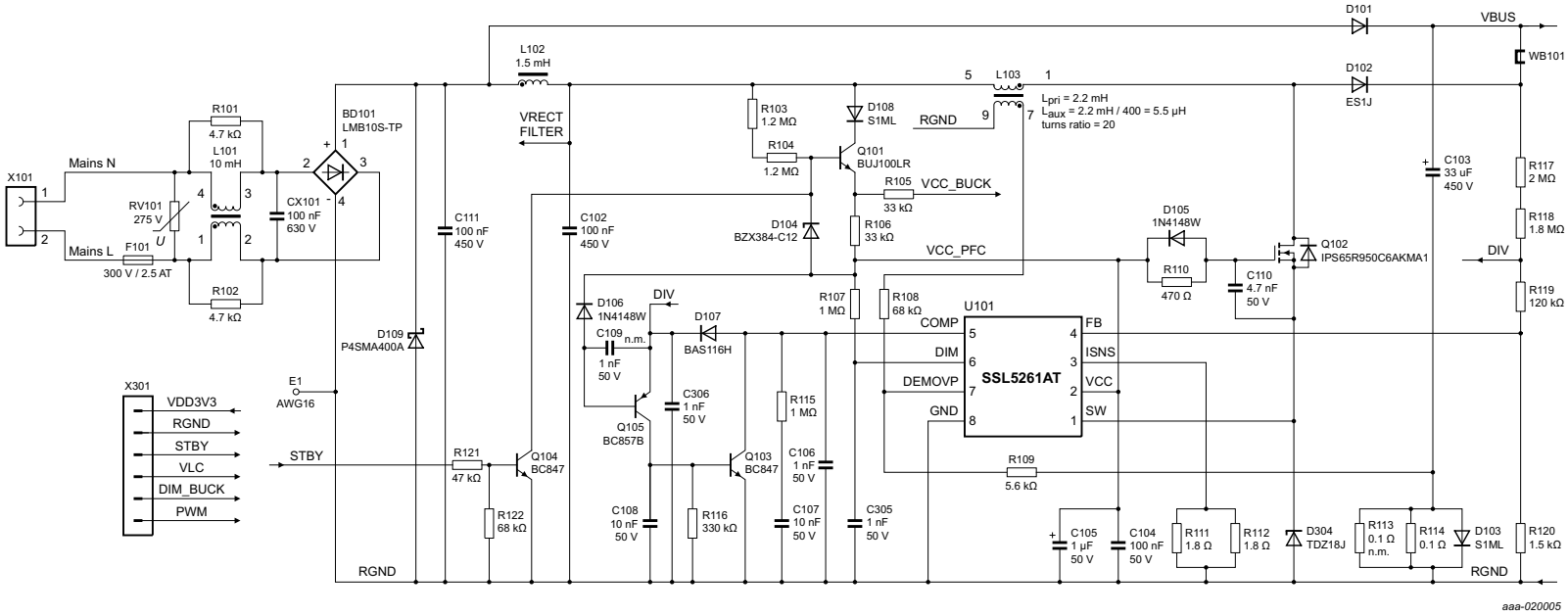

Fig 10. SSL5261DB1350 demo board schematic with PFC controller part featuring SSL5261AT

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8.2 3.3 V microcontroller/auxiliary supply

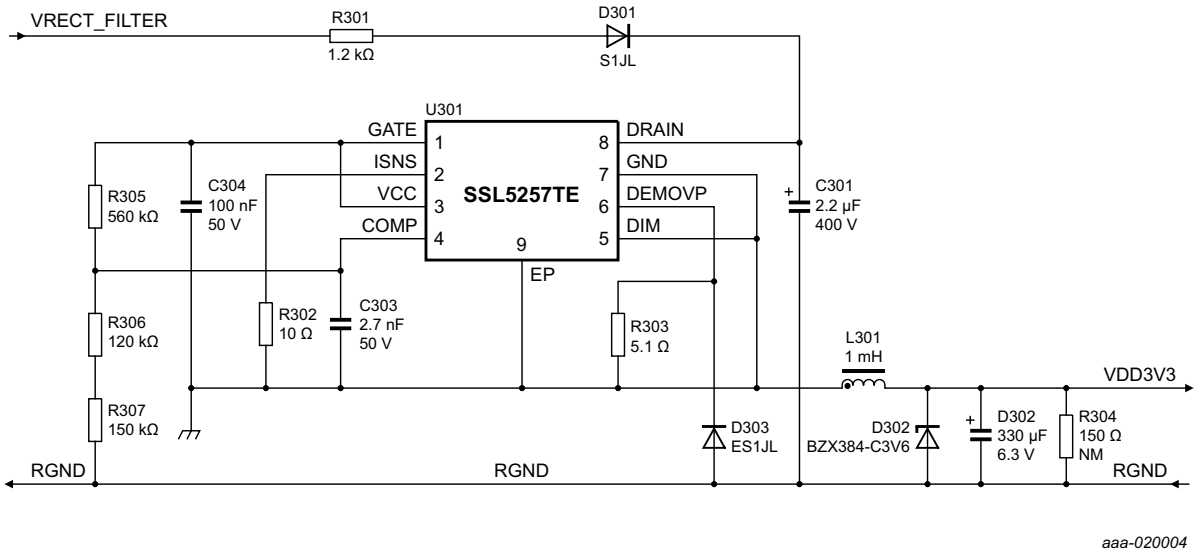

Fig 11. SSL5261DB1350 demo board schematic with 3.3 V microcontroller/auxiliary part featuring SSL5257TE

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8.3 Buck controller

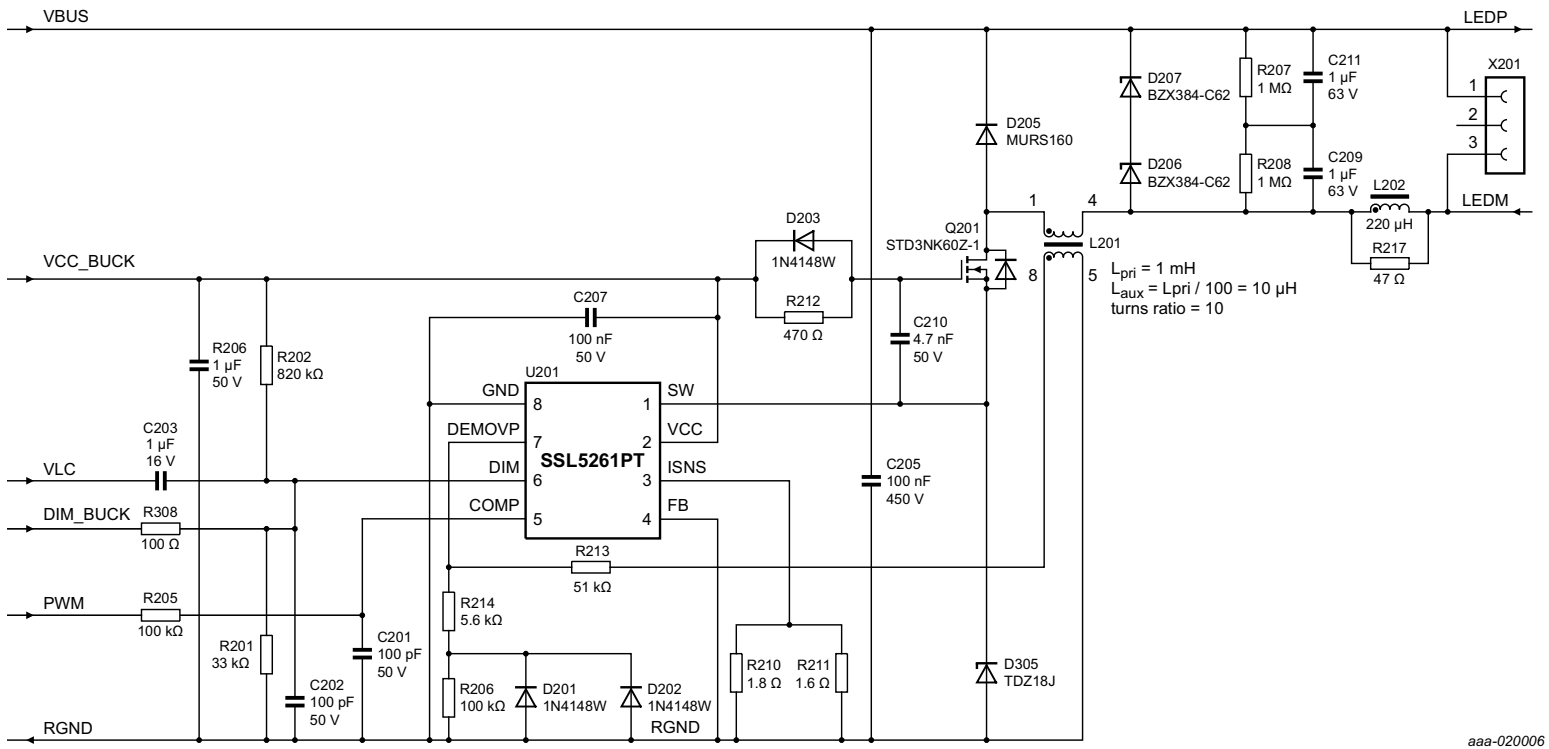

Fig 12. SSL5261DB1350 demo board schematic with buck controller part featuring SSL5261PT

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9. Bill Of Materials (BOM)

Table 2. SSL5261DB1350 demo board BOM

Reference	Description and values	Part number	Manufacturer
BD101	diode; bridge; 1 kV; 1 A	LMB10S-TP	MCC
C210	capacitor; 4.7 nF; 10 %; 50 V; X7R; 0603	-	-
C211	capacitor; 1 μF; 10 %; 63 V; PET; THT	B32529C105K189	EPCOS
C301	capacitor; 2.2 μF; 20 %; 400 V; ALU; THT	ECA2GHG2R2	Panasonic
C302	capacitor; 330 μF; 20 %; 6.3 V; ALU; THT	MCUMR6V3337M8X5	Multicomp
C303	capacitor; 2.7 nF; 10 %; 50 V; X7R; 0603	-	-
C304	capacitor; 100 nF; 10 %; 50 V; X7R; 0603	-	-
C305; C306	capacitor; 1 nF; 10 %; 50 V; X7R; 0603	-	-
CX101	capacitor; 100 nF; 20 %; 630 V; PET; THT	BFC233820104	Vishay
D101; D103; D108	diode; 1 kV; 1 A	S1ML	Taiwan Semiconductor
D102	diode; 600 V; 1 A	ES1J	Fairchild
D104	diode; Zener; 12 V; 250 mA	BZX384-C12	NXP Semiconductors
D105; D201; D202; D203	diode; 100 V; 300 mA	1N4148W-7-F	Diode Inc
D109	diode; TVS; 400 V; 800 mA	P4SMA400A	Littelfuse
D205	diode; 600 V; 1 A	MURS160-E3-52T	Vishay
D206; D207	diode; Zener; 62 V; 300 mA	BZX384-C62	NXP Semiconductors
D301	diode; 420 V; 1 A	S1JL	Taiwan Semiconductor
D302	diode; Zener; 3.6 V; 250 mA	BZX384-C3V6	NXP Semiconductors
D303	diode; 420 V; 1 A	ES1JL	Taiwan Semiconductor
D304; D305	diode; Zener; 18 V; 250 mA	TDZ18J	NXP Semiconductors
F101	fuse; slow blow; 300 V; 2.5 A	38312500000	Littelfuse
L101	inductor; common-mode; 10 mH; 700 mA	744821110	Würth Elektronik
L102	inductor; 1.5 mH; 10 %; 700 mA	RFC1010B-155KE	Coilcraft
L103	inductor; 2.3 mH	750315571	Würth Elektronik
L201	inductor; 1 mH	750315572	Würth Elektronik
L202	inductor; 220 μF; 20 %; 1.3 A; THT	7447471221	Würth Elektronik
L301	inductor; 1 mH; 170 mA	22R105C	Murata
Q101	transistor; NPN; 400 V; 1 A	BUJ100LR	NXP Semiconductors
Q102	MOSFET-N; 650 V; 4.5 A	IPS65R950C6AKMA1	Infineon
Q103; Q104	transistor; NPN; 45 V; 100 mA	BC847	NXP Semiconductors
Q105	transistor; PNP; 400 V; 300 mA	BC857B,215	NXP Semiconductors
Q201	MOSFET-N; 600 V; 2.4 A	STD3NK60Z-1	STMicroelectronics
R101; R102	resistor; 4.7 kΩ; 1 %; 100 mW; 0805	-	-
R103; R104	resistor; 1.2 MΩ; 1 %; 250 mW; 1206	-	-
R105; R106	resistor; 33 kΩ; 1 %; 100 mW; 0603	-	-
R107; R115	resistor; 1 MΩ; 1 %; 63 mW; 0603	-	-
R108; R122	resistor; 68 kΩ; 1 %; 63 mW; 0603	-	-
R109	resistor; 5.6 kΩ; 1 %; 250 mW; 1206	-	-

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Table 2. SSL5261DB1350 demo board BOM *…continued*

Reference	Description and values	Part number	Manufacturer
R110; R212	resistor; 470 Ω; 1 %; 100 mW; 0603	-	-
R111; R112	resistor; 1.8 Ω; 1 %; 1 W; 2512	ERJ1TRQF1R8U	Panasonic
R113	resistor; 0.1 Ω; 1 %; 1 W; 2512	RL2512FK-070R1L	Yageo
R114	resistor; 0.1 Ω; 5 %; 1 W; RSMF; THT	RSMF1JTR100	Stackpole Electronics
R116	resistor; 330 kΩ; 1 %; 63 mW; 0603	-	-
R117	resistor; 2 MΩ; 1 %; 250 mW; 1206	-	-
R118	resistor; 1.8 MΩ; 1 %; 250 mW; 1206	-	-
R119	resistor; 120 kΩ; 1 %; 63 mW; 0603	-	-
R120	resistor; 1.5 kΩ; 1 %; 100 mW; 0603	-	-
R121	resistor; 47 kΩ; 1 %; 100 mW; 0603	-	-
R201	resistor; 33 kΩ; 1 %; 100 mW; 0603	-	-
R202	resistor; 820 kΩ; 1 %; 63 mW; 0603	-	-
R206	resistor; 100 kΩ; 1 %; 63 mW; 0603	-	-
R207; R208	resistor; 1 MΩ; 1 %; 250 mW; 1206	-	-
R210	resistor; 1.8 Ω; 1 %; 500 mW; 0805	-	-
R211	resistor; 1.6 Ω; 1 %; 500 mW; 0805	-	-
R213	resistor; 51 kΩ; 1 %; 63 mW; 0603	-	-
R214	resistor; 5.6 kΩ; 1 %; 63 mW; 0603	-	-
R217	resistor; 47 Ω; 1 %; 100 mW; 0805	-	-
R301	resistor; 1.2 kΩ; 5 %; 1 W; PR01; THT	PR01000101201JR500	Vishay
R302	resistor; 10 Ω; 1 %; 100 mW; 0805	-	-
R303	resistor; 5.1 Ω; 5 %; 250 mW; 1206	-	-
R304	resistor; 150 Ω; 1 %; 100 mW; 0805	-	-
R305	resistor; 560 kΩ; 5 %; 63 mW; 0603	-	-
R306	resistor; 120 kΩ; 5 %; 63 mW; 0603	-	-
R307	resistor; 150 kΩ; 5 %; 63 mW; 0603	-	-
R308	resistor; 100 Ω; 1 %; 63 mW; 0603	-	-
RV101	resistor; MOV; 275 V; 75 J	V275LA20AP	Littelfuse
U101	LED driver; SSL5261AT	SSL5261AT	NXP Semiconductors
U201	LED driver: SSL5261PT	SSL5261PT	NXP Semiconductors
U301	LED driver: SSL5257TE	SSL5257TE	NXP Semiconductors
WB101	wire bridge; 0.8 mm; pitch = 10.16 mm	923345-04	3 M
X101	terminal block; 2-way; pitch = 10.16 mm	OSTTC023162	On-Shore Tech. Inc.
X201	terminal block; 3-way; pitch = 5.08 mm	PM5.08/3/90 BLK	Weidmüller
X301	header; straight; 1 row × 6-pin; pitch = 2.54 mm	22-28-4060	Molex

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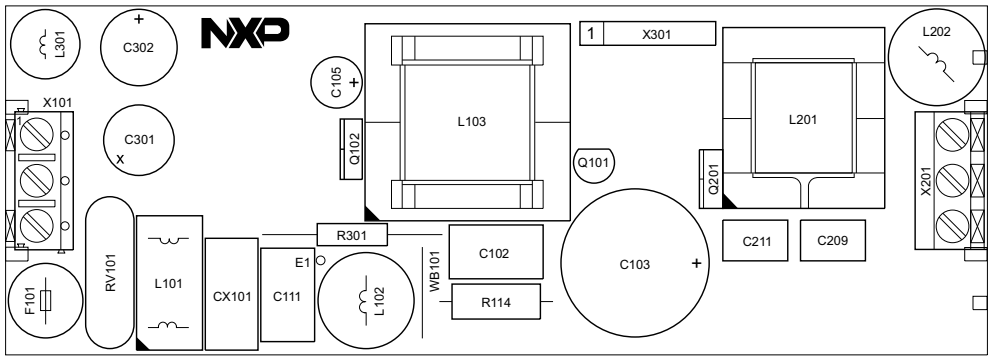
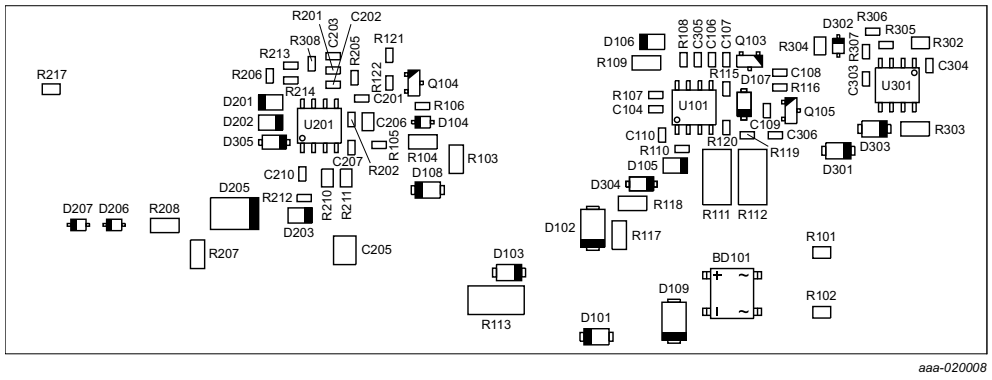
10. PCB assembly and layout SSL5261DB1350



a. Top



b. Bottom

Fig 13. SSL5261DB1350 demo board PCB assembly

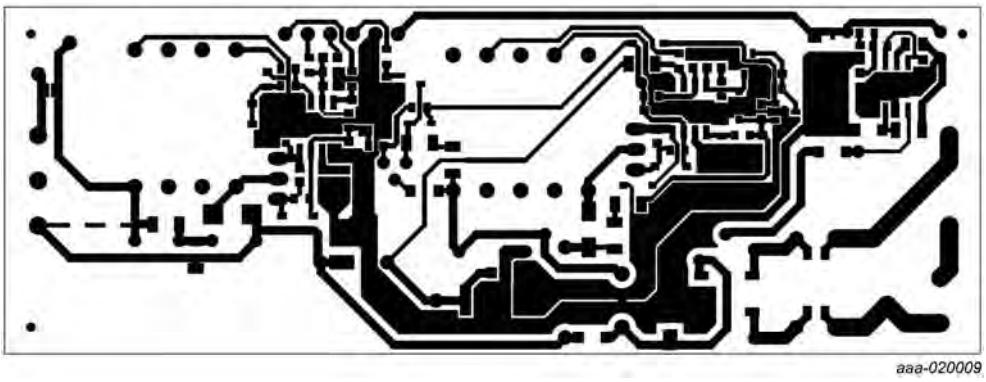


Fig 14. SSL5261DB1350 demo board layout

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11. PFC and buck inductor specifications

11.1 PFC inductor

The PFC transformer is EE20/10/6, 10 pins, THT, horizontal (EF20).

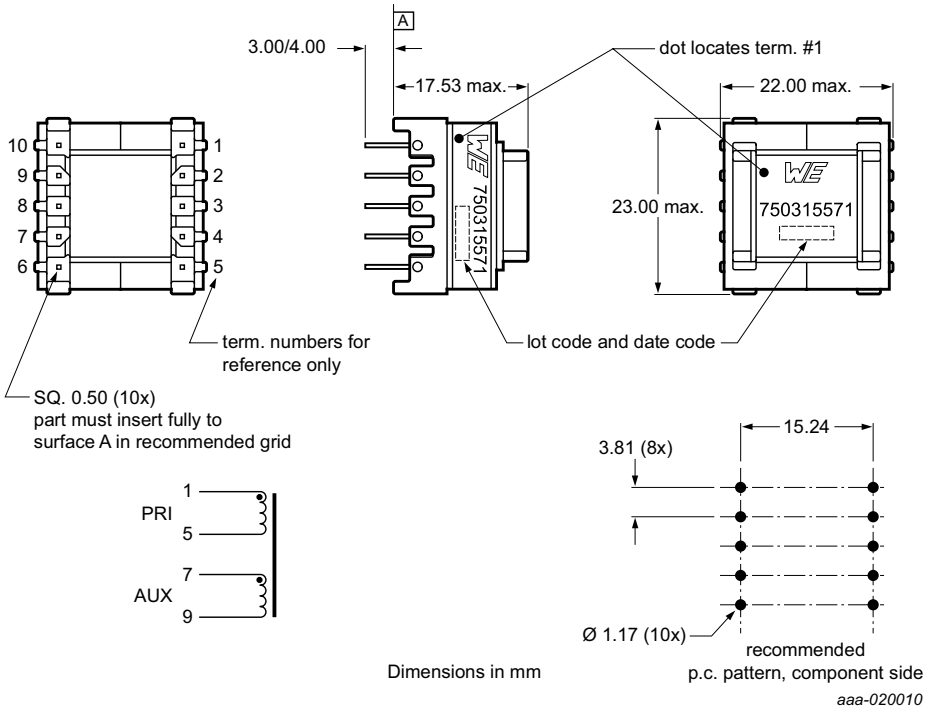

Fig 15. PFC inductor schematic

Table 3. Electrical specifications PFC inductor

All values are specified at 25 °C unless otherwise specified.

Parameter	Value	Conditions
DC resistance (1-5)	3.9 Ω; ±10 %	20 °C
DC resistance (7-9)	0.233 Ω; ±10 %	20 °C
primary inductance (1-5)	2.2 mH; ±10 %	100 mV; 10 kHz
leakage inductance (1-5)	150 µH nominal; 250 µH maximum	short (7-9); 100 mV; 10 kHz
saturation current (1-5)	1 A	
turns ratio	20:1; ±1 % tolerance	(1-5):(7-9)

Table 4. PFC inductor construction

Wire	Description
primary wire	10-strand 0.07 mm litz wire
primary number of turns	205 turns wound uniformly in 12 layers
auxiliary wire	10-strand 0.07 mm litz wire
auxiliary number of turns	10 turns wound uniformly in 1 layer

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11.2 Buck inductor

The buck inductor is EE16/8/5, 8 pins, THT, horizontal (EF16).

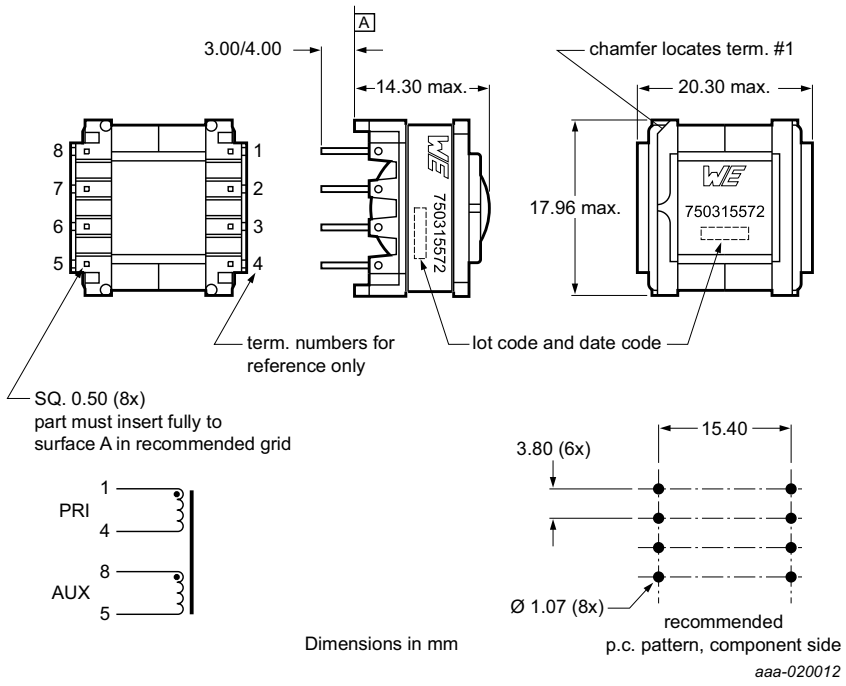

Fig 16. Buck inductor schematic

Table 5. Electrical specifications buck inductor

All values are specified at 25 °C unless otherwise specified.

Parameter	Value	Conditions
DC resistance (1-4)	1.85 Ω; ±10 %	20 °C
DC resistance (8-5)	0.22 Ω; ±10 %	20 °C
primary inductance (1-4)	1 mH; ±10 %	100 mV; 10 kHz
leakage inductance (1-4)	28 µH nominal; 40 µH maximum	short (8-5); 100 mV; 10 kHz
saturation current (1-5)	750 mA	
turns ratio	10:1; ±1 % tolerance	(1-4):(8-5)

Table 6. Buck inductor construction

Wire	Description
primary wire	8-strand AWG41 litz wire
primary number of turns	125 turns wound uniformly in 6 layers
auxiliary wire	8-strand AWG41 litz wire
auxiliary number of turns	13 turns wound uniformly in 1 layer

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12. Abbreviations

Table 7. Abbreviations

Acronym	Description
BCM	Boundary Conduction Mode
CEM-3	Composite Epoxy Material 3
EMI	ElectroMagnetic Interference
FR4	Flame Retardant 4 grade
LED	Light-Emitting Diode
OSP	Output Short Protection
OVP	OverVoltage Protection
PCB	Printed-Circuit Board
PFC	Power Factor Correction
PWM	Pulse-Width Modulation
SSL	Solid-State Lighting
VLC	Visual Light Communication

13. References

[1] **SSL5261AT data sheet —** *Mains dimmable LED driver IC*; 2015, NXP Semiconductors

[2] **SSL5261PT data sheet —** *Mains dimmable LED driver IC*; 2015, NXP Semiconductors

[3] **SSL5257TE data sheet —** *Mains dimmable buck-boost LED driver IC 10 Ohm/700 V*; 2015, NXP Semiconductors

[4] **UM10904 user manual —** *SSL5257DB1351 3.3 V standby/auxiliary power supply to power a microcontroller for smart lighting interfaces; 2015*, NXP Semiconductors

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